The Emerging Battery Market

Navigating Safety Challenges

SCANDINAVIAN CONFERENCE ON SYSTEM & SOFTWARE SAFETY, GOTHENBURG

Anton Nytén

20.11.2024

etteplan

What can go wrong?

20th of June 2023

A fire starts in an e-bike repair shop in New York killing 4 people that were asleep in the apartments situated above the shop.

Source: The Guardian

Presenter

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Etteplan Sweden AB
Battery Technology Director

Development of battery systems, battery safety, regulatory requirements and evaluating battery suppliers.

St Jude Medical
Principal Battery Expert

Development of battery systems for medical devices.

Uppsala University
PhD, Battery Technologies

Fundamental research on Li-ion batteries.

Etteplan

A growth company

A rapidly growing and developing technology service company

Customers among global machine and equipment manufacturers

High-level of competence and service attitude

Founded 1983 | Nasdaq Helsinki Ltd

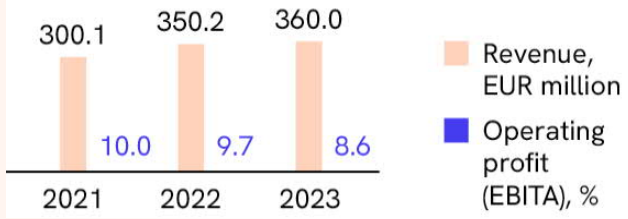
360

REVENUE, EUR MILLION 2023

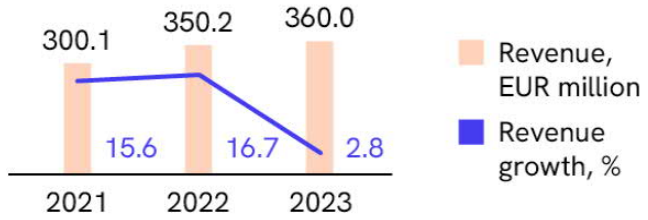
~4,000

INDUSTRY PROFESSIONALS

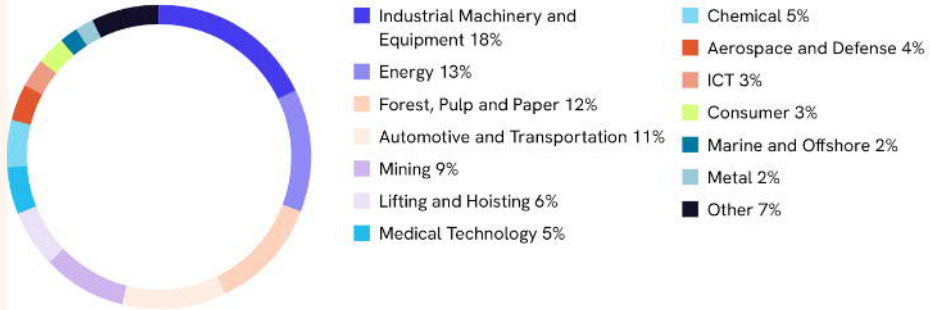
REVENUE AND OPERATING PROFIT (EBITA), %



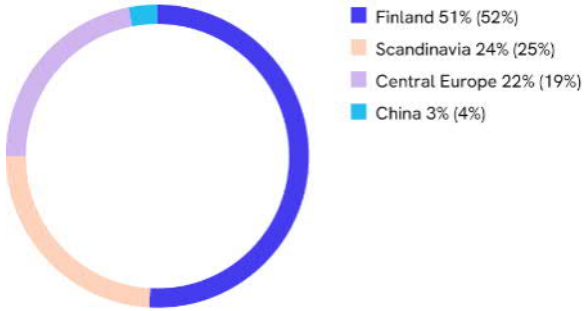
REVENUE AND REVENUE GROWTH, %



REVENUE BY CUSTOMER SEGMENT 2023

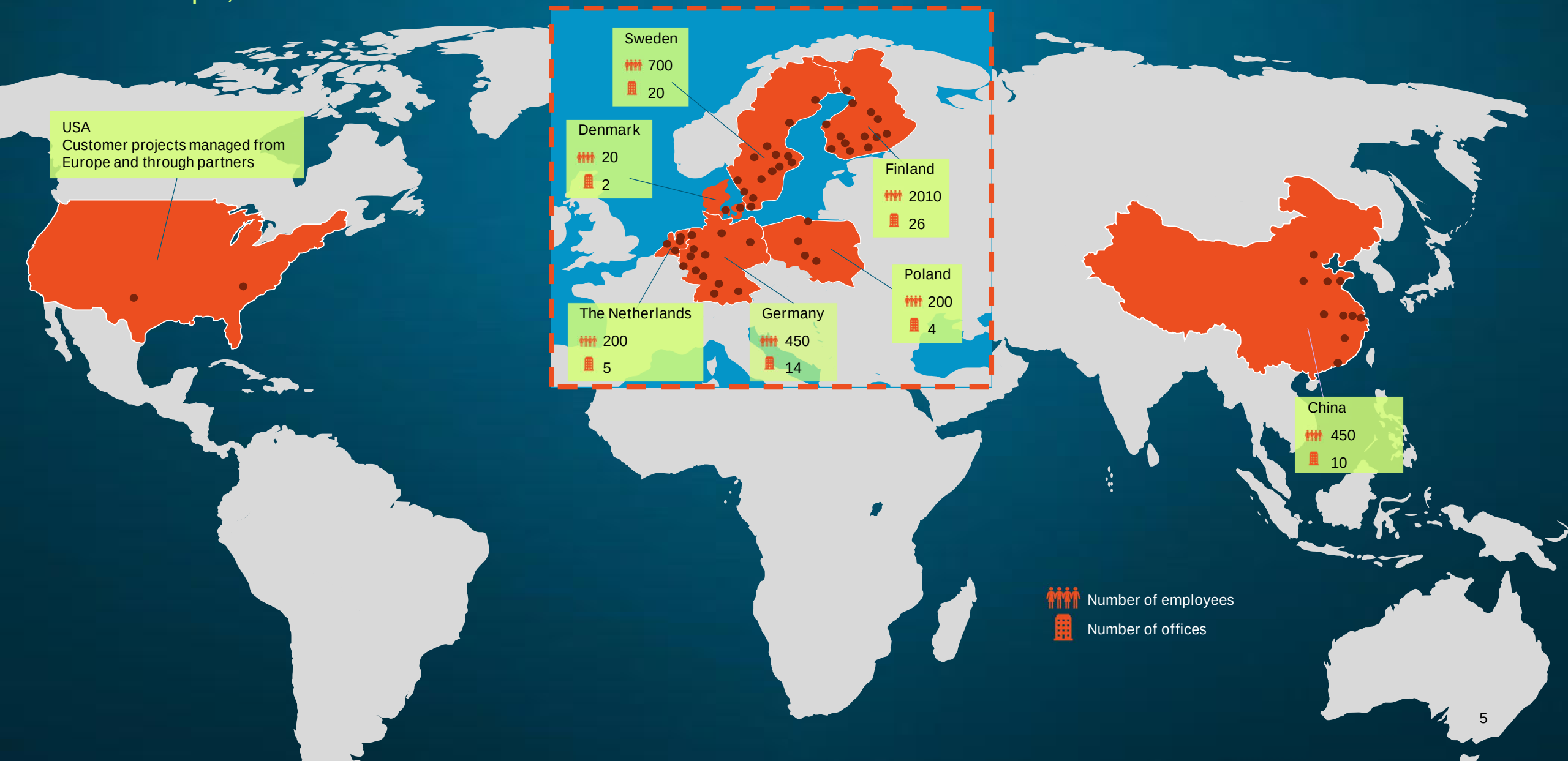


REVENUE BY GEOGRAPHICAL AREA 2023 (2022)



Etteplan Global presence

in Europe, Asia and North America



The Battery Specialist Team

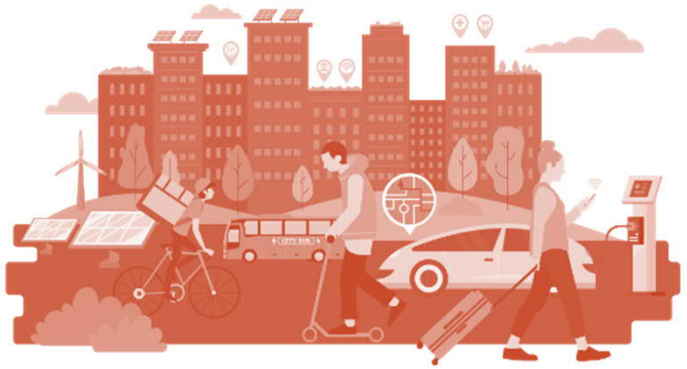
1. Improved product safety
2. Regulatory compliance
3. Cost-efficiency in product development
4. Reduce time-to-market

Creating Value

- Supports customers in achieving safe, reliable, and cost-efficient battery solutions with optimal performance.
- Provides services across a wide range of battery types, including portable power products, automotive, industrial, and stationary batteries.
- Guides clients through every phase, from early development to recycling.
- Leverages a deep industrial and academic background in battery technology.
- Possesses in-depth knowledge of electrochemistry and advanced materials.
- Independent subject matter expertise.

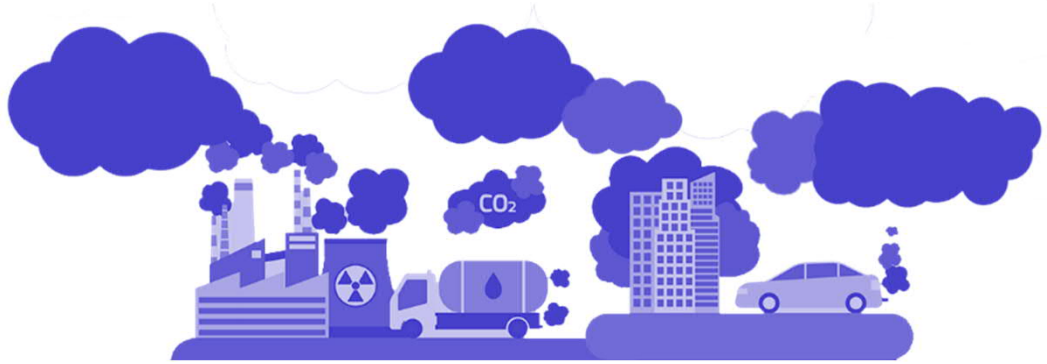
Li-ion battery market trends

Driving Forces Behind Electrification



Urbanization

Renewable energy sources



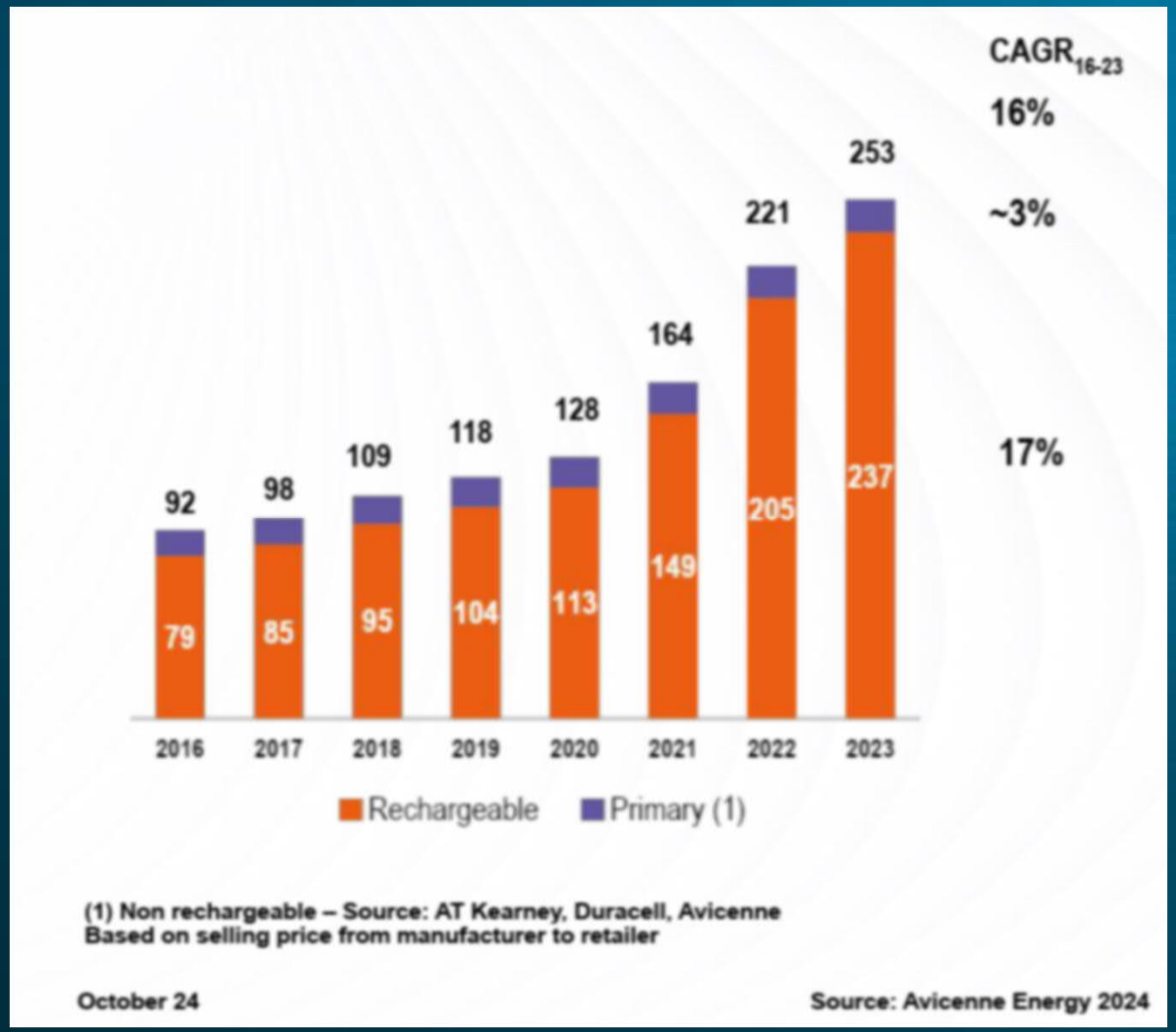
Climate awareness

Sweden aims to become carbon neutral by 2045

Driving Forces Behind Electrification
from the perspective of a specific industry – Mining

- Cost reduction
- Work environment
- CO_2 reduction
- ”Green” minerals

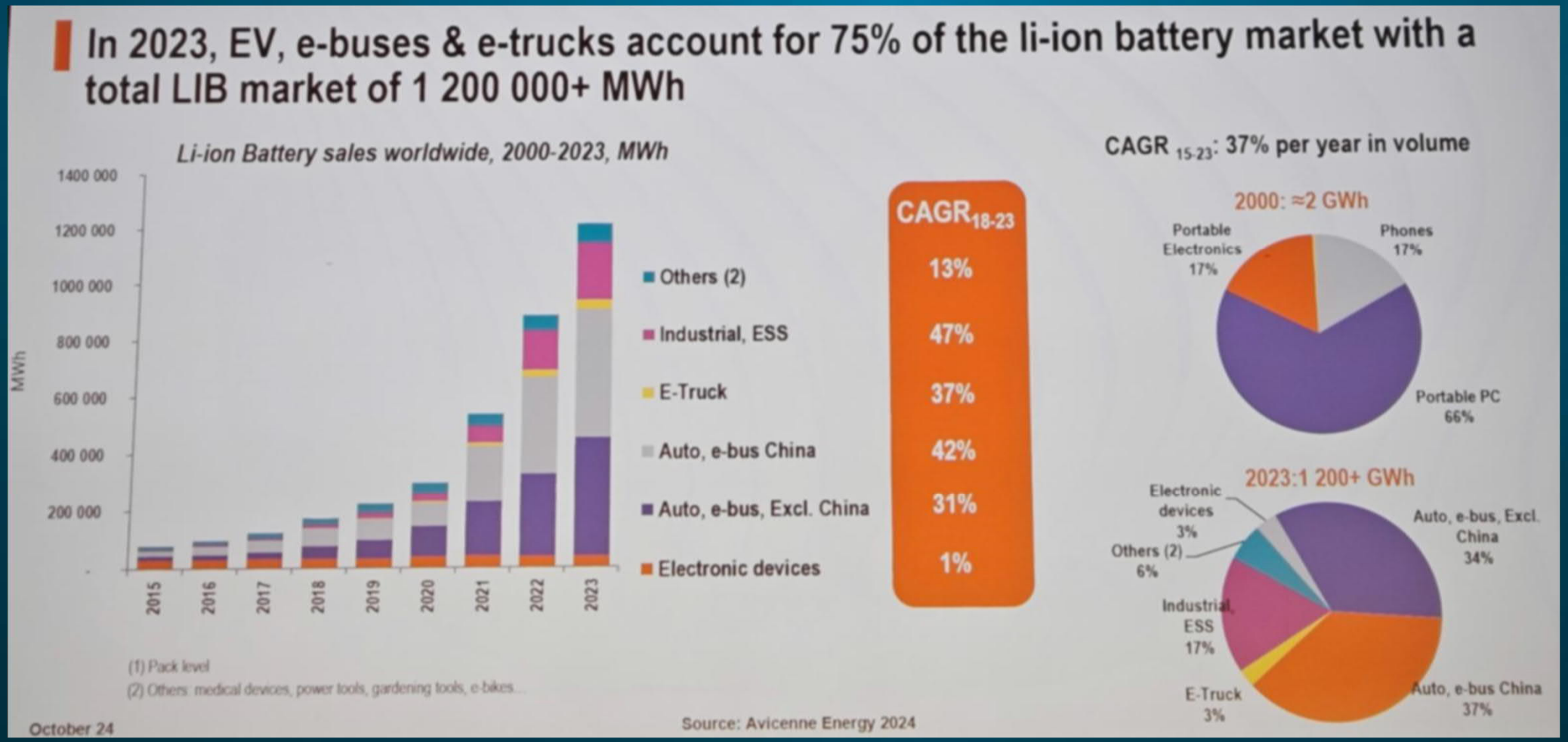
World Battery Market Overview



Battery market in value 2016-2023, worldwide, US$ Bn

Market value 2023: >250 US$ Bn

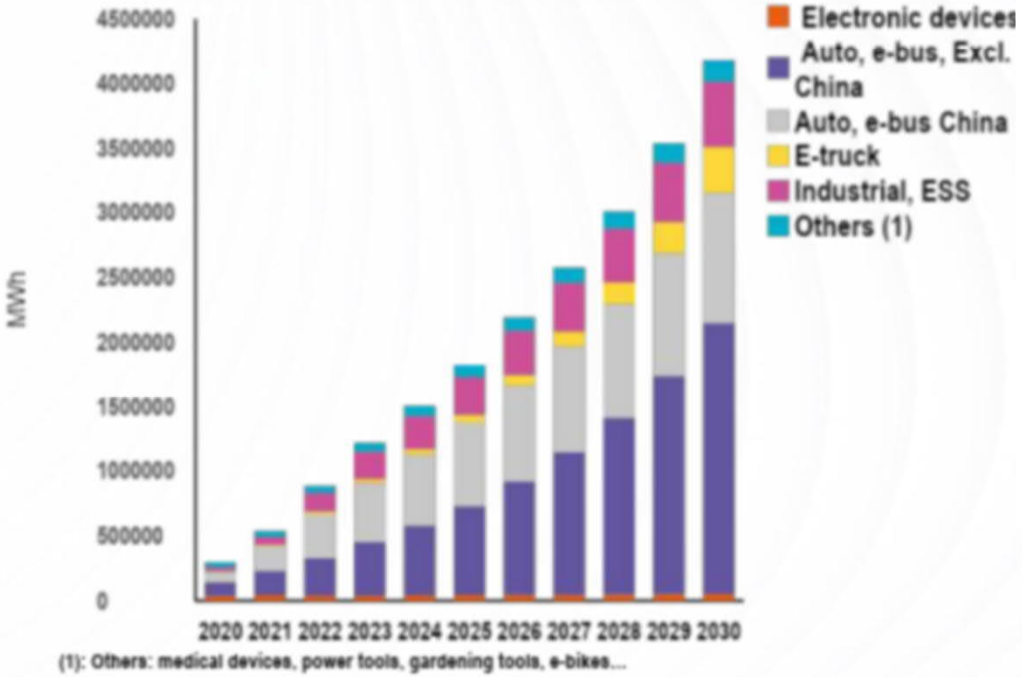
Li-ion Battery Market 2015-2023



Li-ion Battery Market 2020-2030

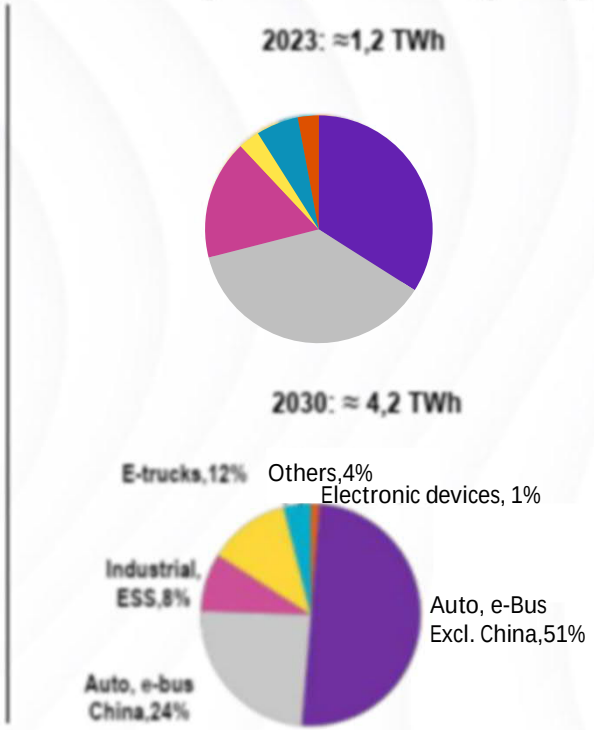
The Lithium-ion battery market will grow from ≈+1200 GWh in 2023 to ≈4,200 GWh in 2030, with a $CAGR_{20-30}$ of 30% in volume

Li-ion Battery sales, Worldwide, 2000-2030, MWh



(1): Others: medical devices, power tools, gardening tools, e-bikes...

Li-ion Battery sales, Worldwide, per application :



October 24

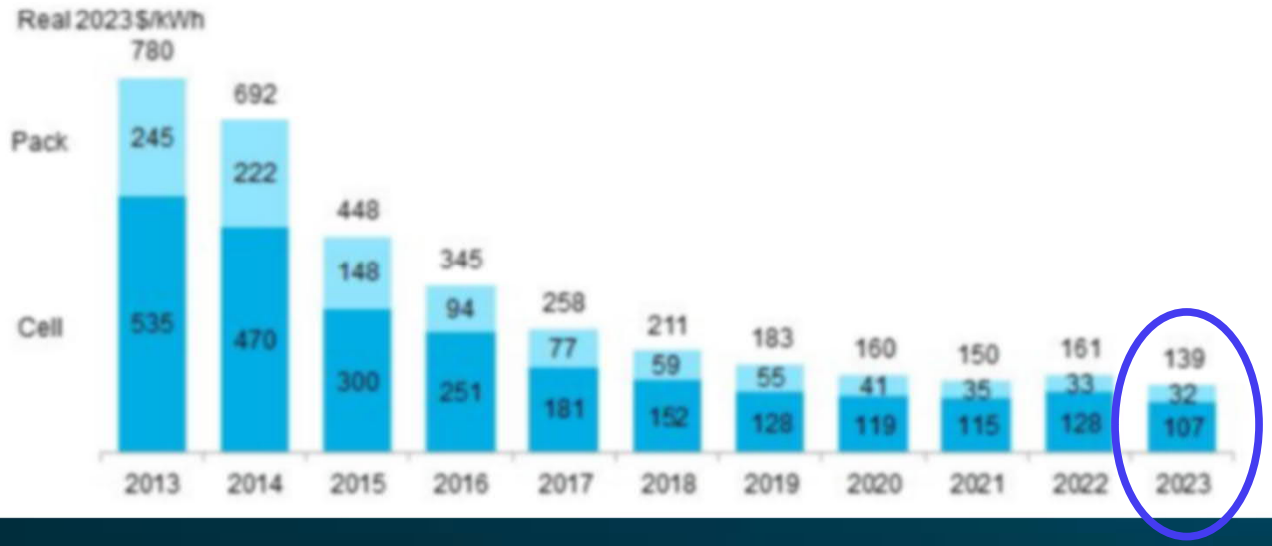
Source: Avicenne Energy 2024

Battery Pack Prices 2013-2023

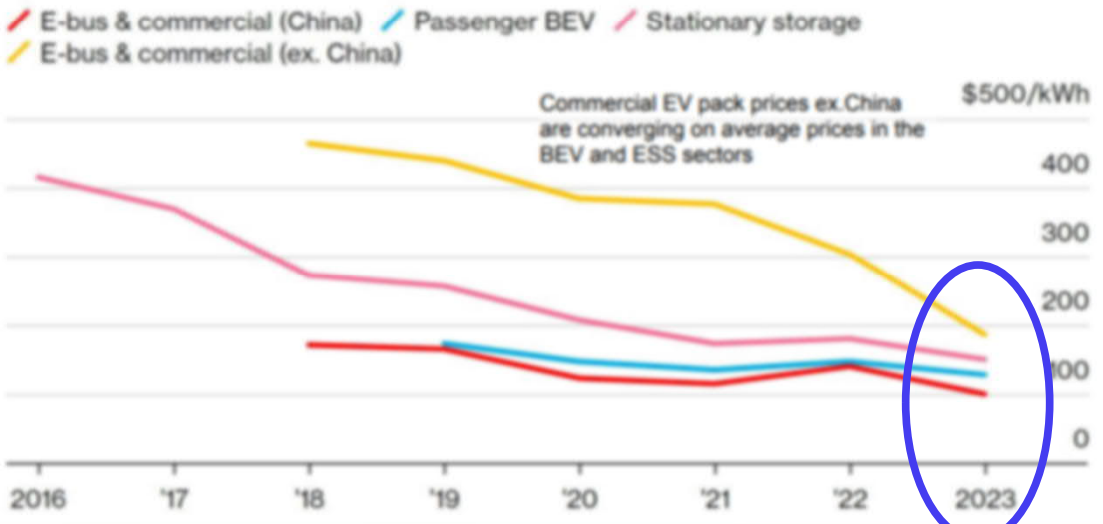
Battery prices resume long trend of decline after unprecedented increase in 2022

- Average pack price dropped 14% to a record low of $139/kWh
- This was driven by raw material and component prices falling while production capacity overshot demand
- Prices were lowest in China, followed by US and then Europe. There was intense price competition in a crowded market in China
- LFP cells were 32% cheaper than NMC cells

Pack-to-cell price ratio is recently plateauing at ~1:5



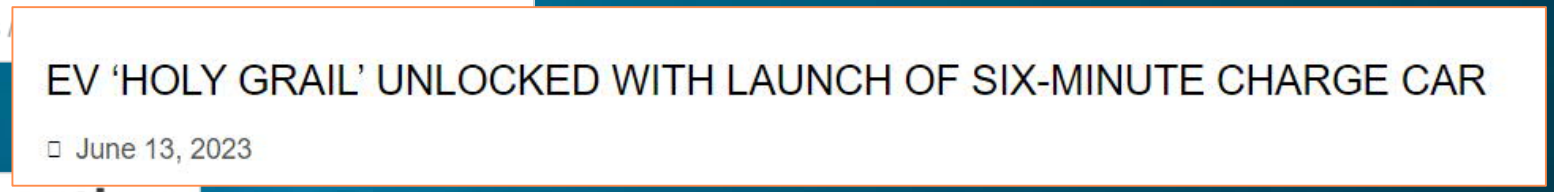
Prices are converging across sectors



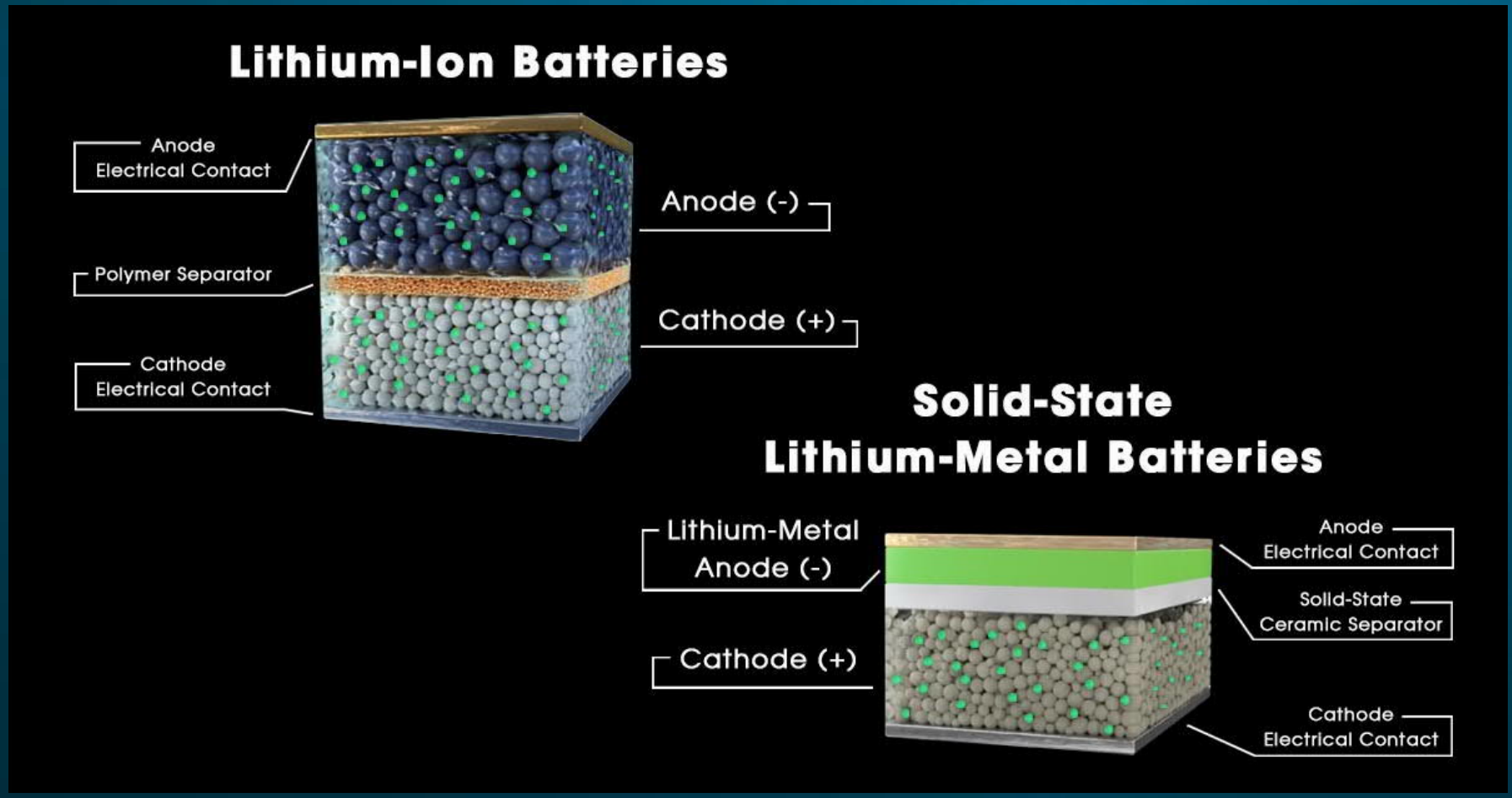
Source | Volta Foundation. Battery Report 2023

Future batteries

Solid-state batteries in the news



Solid-state batteries



Advantages:

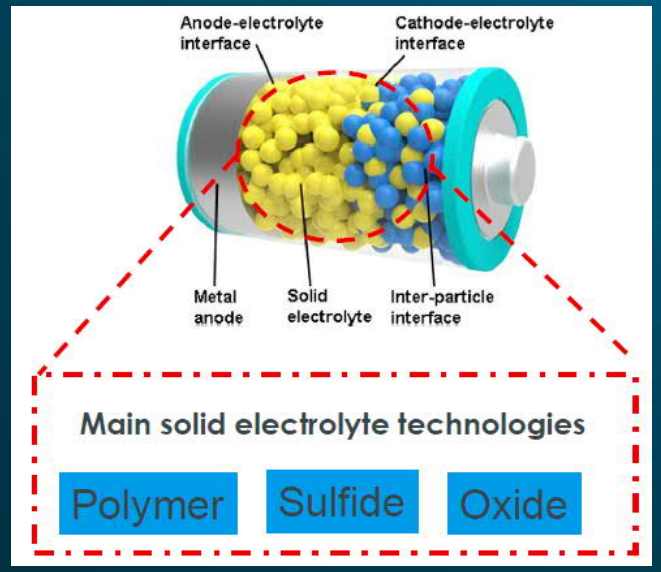
- Increased energy density
- Enhanced safety
- Stability & durability

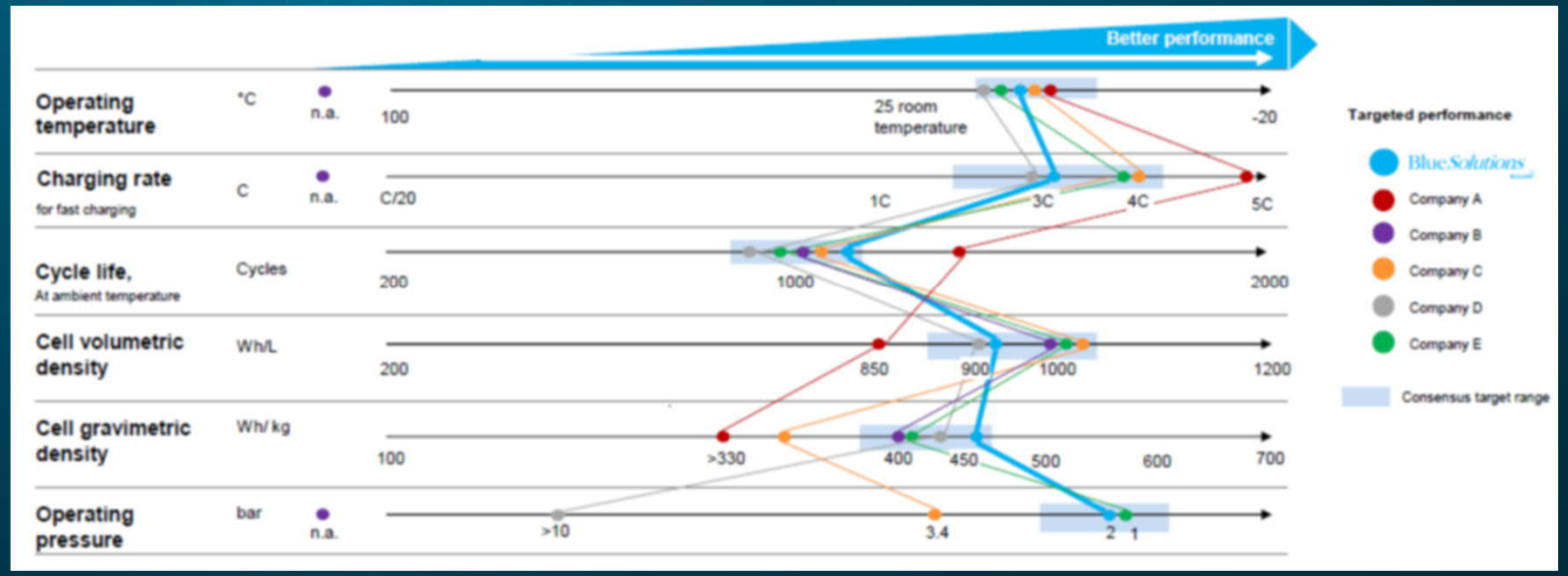
Technological challenges:

- Power capability
- Reduced lifetime performance
- Production cost

Solid-state batteries

- *“Still 5 years away…”*
- Key challenges remain for many companies:
  - Develop room temperature solid electrolyte
  - All solid-state batteries
  - Swelling/Stable interfaces between materials
  - Industrial scale up of new materials and new processes





Source | Alexandre Dominget, SAFT/Total, Sriram Ramanoudjame, BlueSolutions, *Batteries 2022*

Sodium-ion (Na-ion) Batteries

Na-ion vs. Li-ion batteries:
Complementary rather than competitive

- Na-ion is not a revolution but an evolution
- Advances to match LFP cells in terms of energy density
  - Could be suitable for e.g., stationary energy storage and EV busses
- Current research on Na-ion began ~10 years ago
  - 10-20 years to commercialize a new material in the battery industry

Source | JM Tarascon, College de France, Hevré Beuffe, TIAMAT, *Batteries 2022*

Avoid Delayed Cost

Avoid Delayed Cost of Extracting Defects

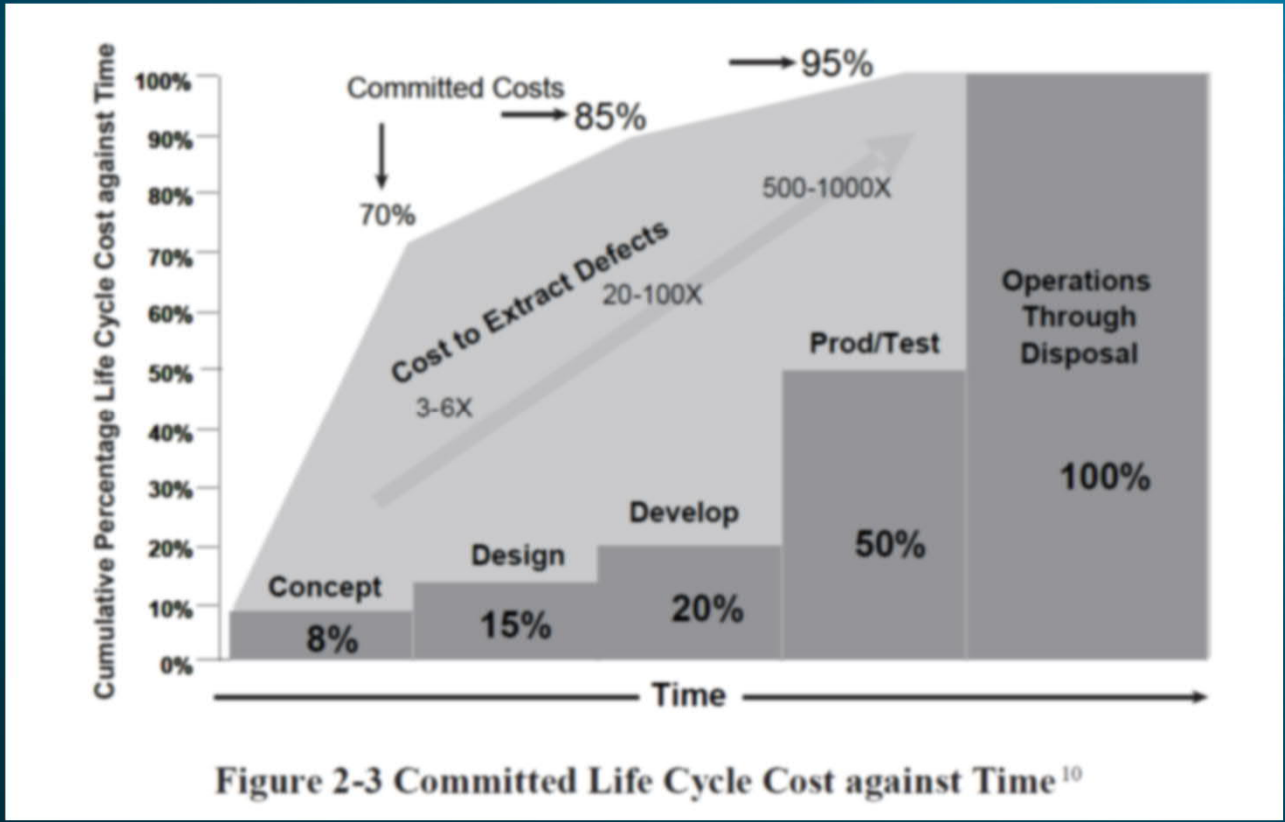


Figure 2-3 Committed Life Cycle Cost against Time [10]

Source | INCOSE handbook

a) Investments in early development pays off
   E.g. Focus on battery system safety vs. cell safety

b) Identify key product specifications – DON'T RUSH!

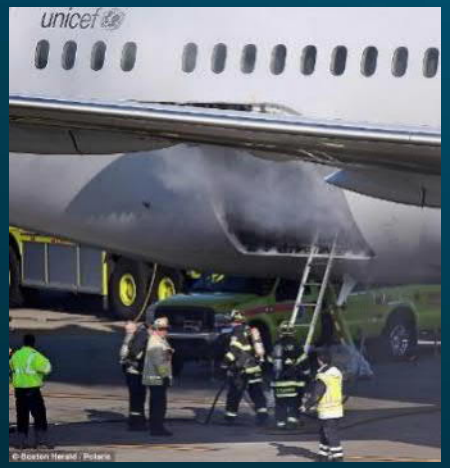
c) Use regulatory safety requirements as guidance
   E.g. the battery regulation EU Regulation 2023/1542 for batteries and UN ECE R100 for battery vehicles

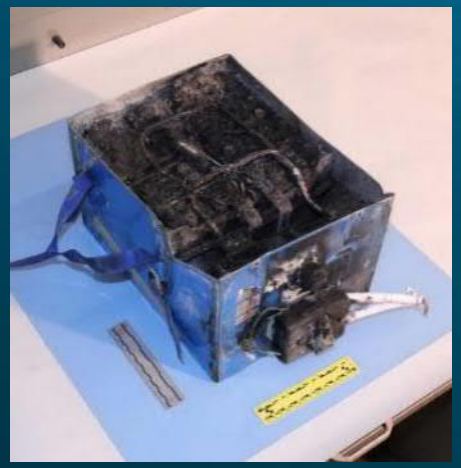
d) CE-marking (industry) or Type approval (vehicles)?
   E.g. ISO 13849-1:2023 which relate to IEC 62619; or the ISO 26262 series for type approval

e) Safety testing on battery system and cells
   E.g. system safety monitoring software tests, and risk mitigation validating tests

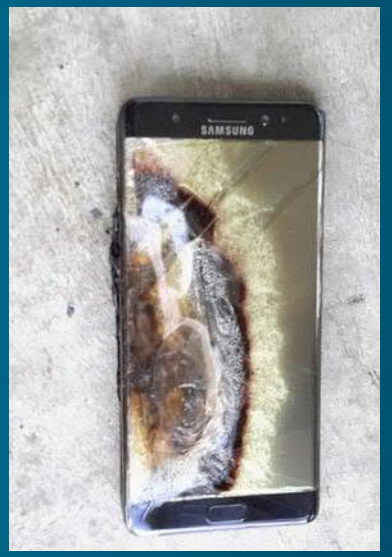
Identifying Key Specifications

Battery fire at Boeing 787 Dreamliner aircrafts - 2013



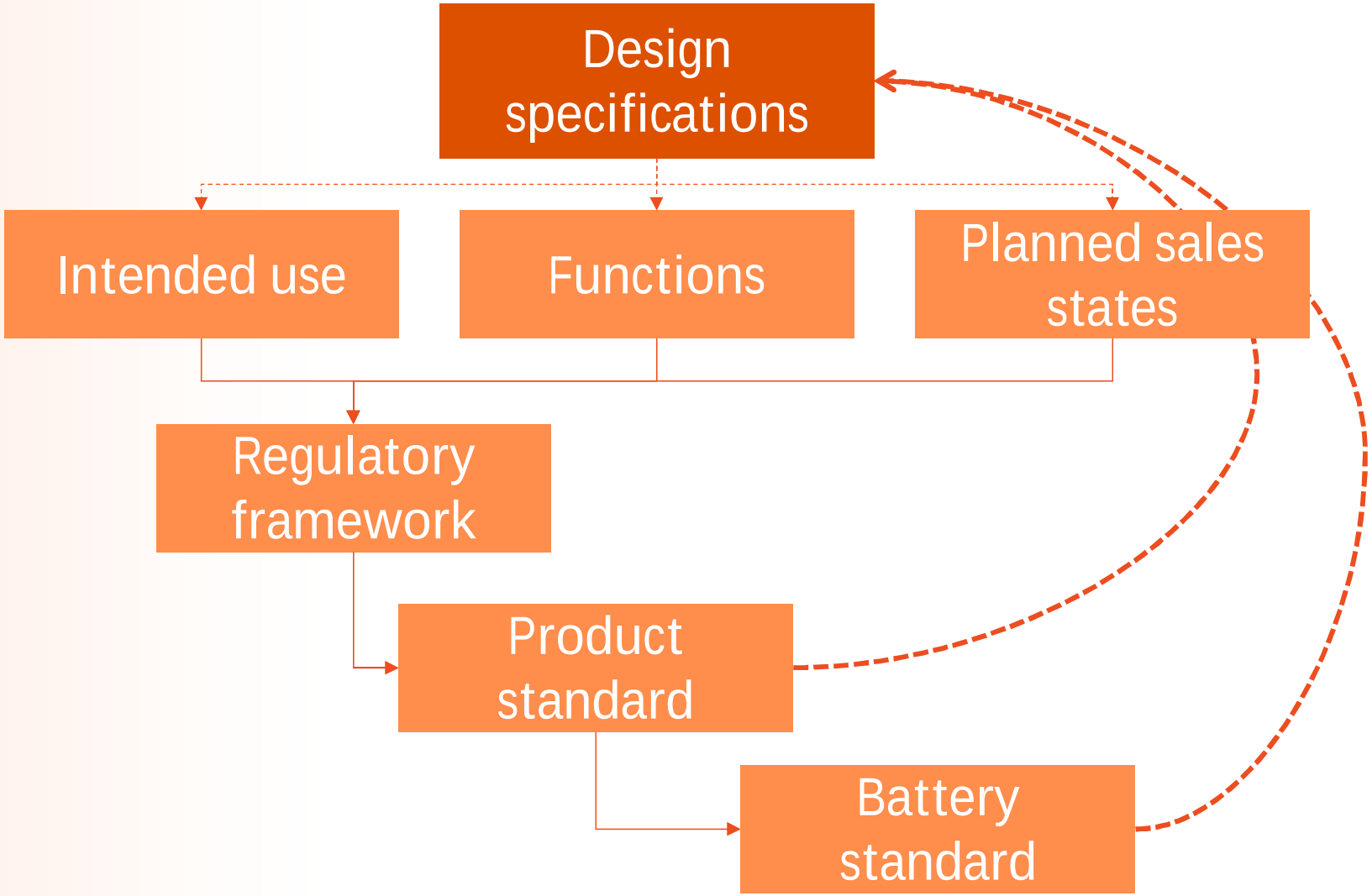


Samsung Galaxy Note 7 - 2016

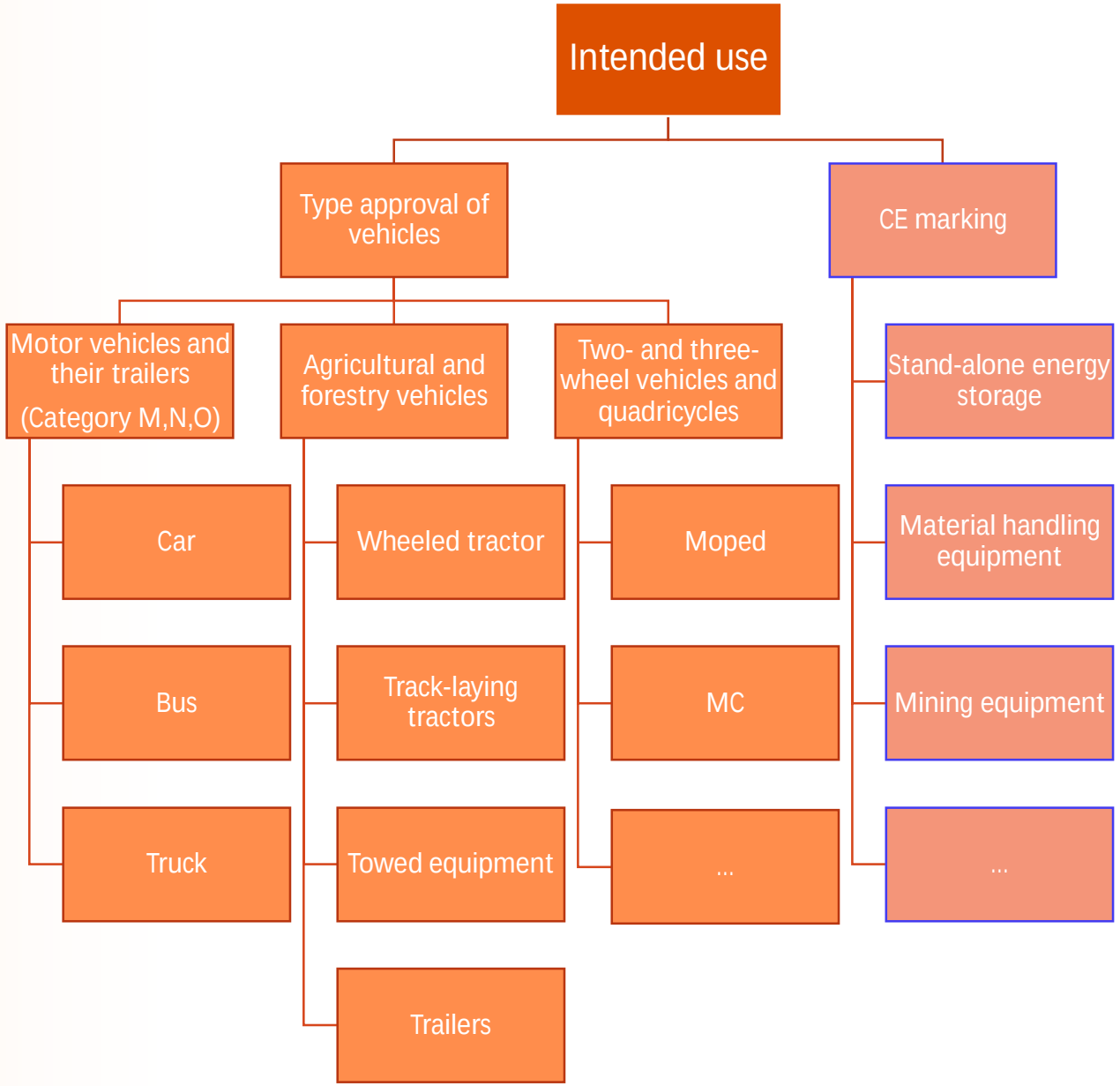


SNCF's mistake: Trains too wide

Regulatory Design Guidance

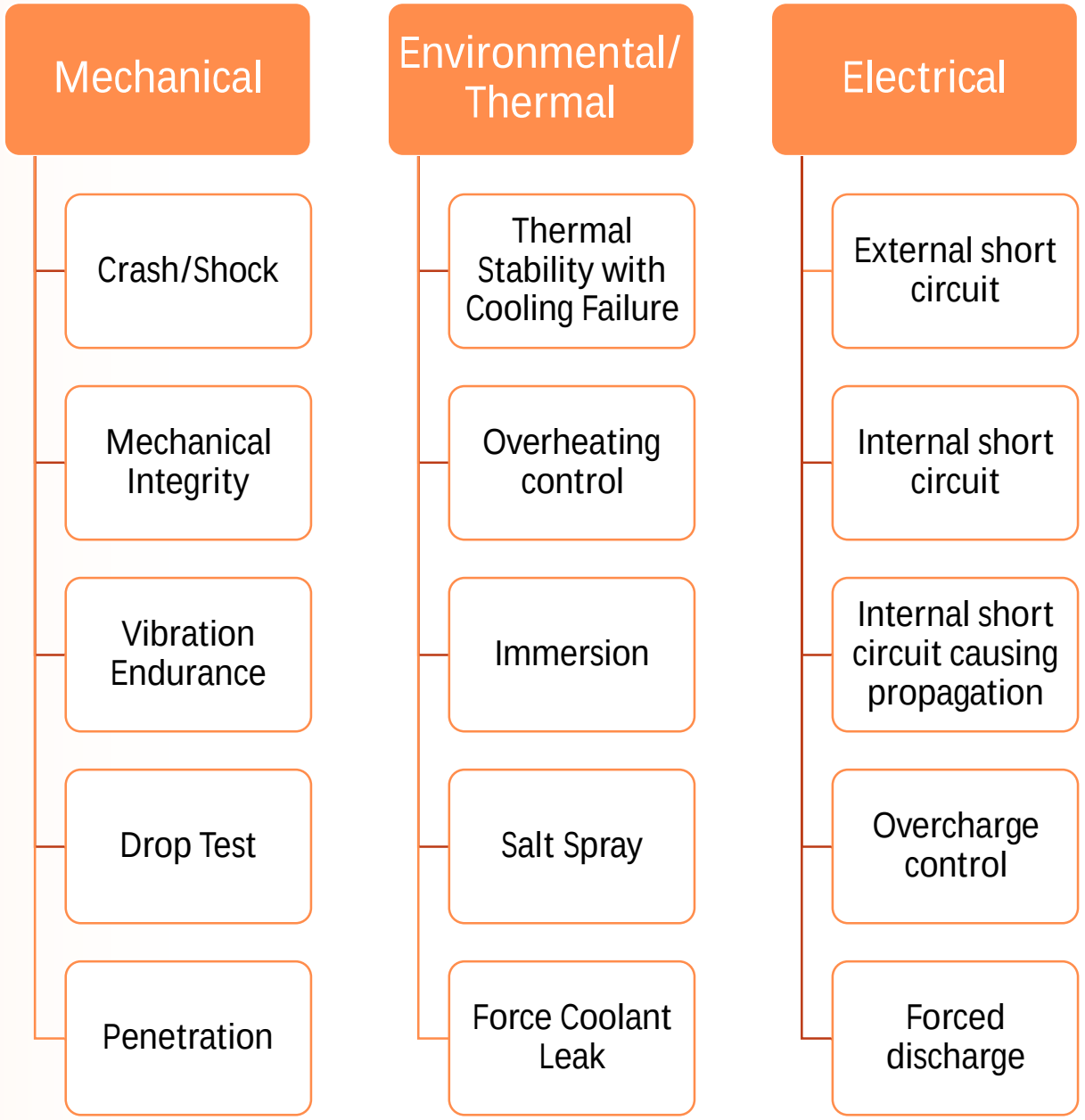


Intended Use...



Safety Tests in Standards and Regulations

- Compliance requirements in regulations
- Design guidance on system safety by CE-marking and Type Approval
- Failure mitigation by passive features or BMS when malfunction detected



A Downside of Guidance by Test Specs.

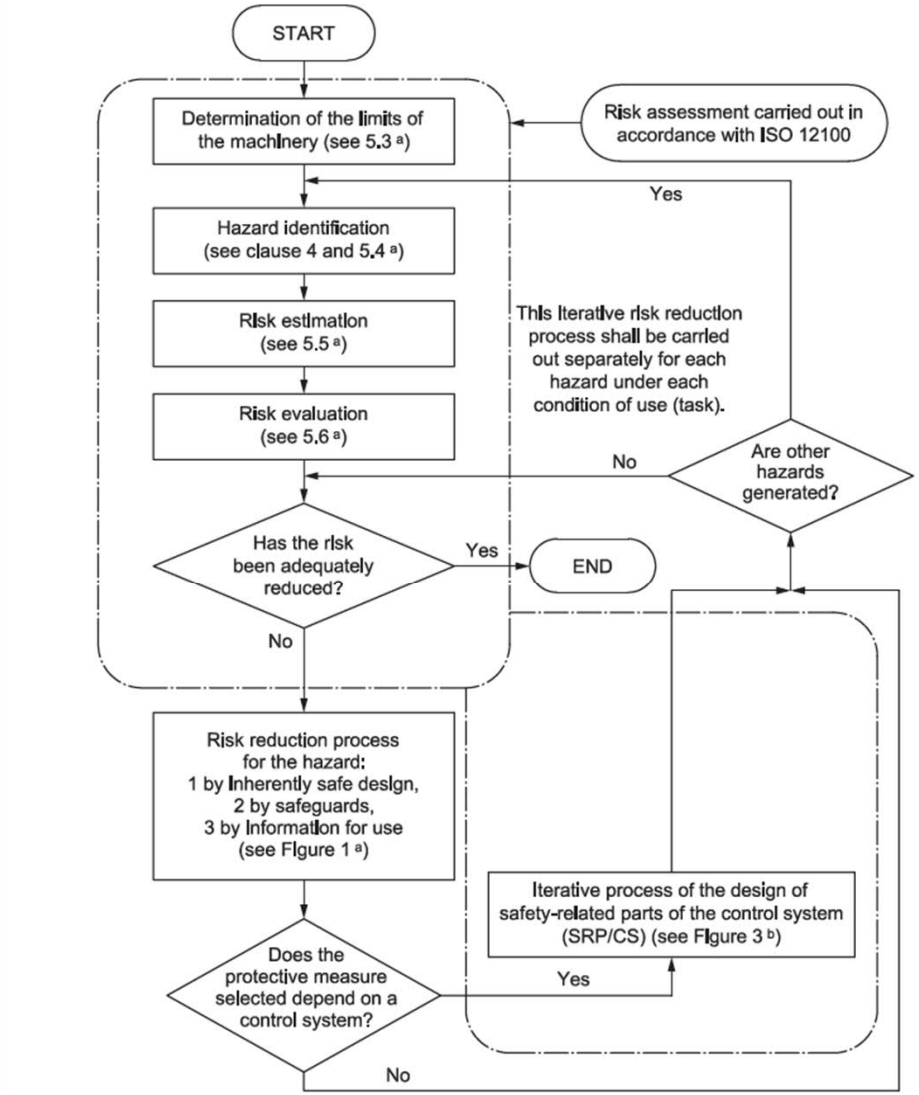
Freedom of Design Restricted?

- Guidance by Test Specifications

  or

- Risk Management Analysis (RiMA)

Design considerations and objectives in design



a Refers to ISO 12100:2010

b Refers to this part of ISO 13849

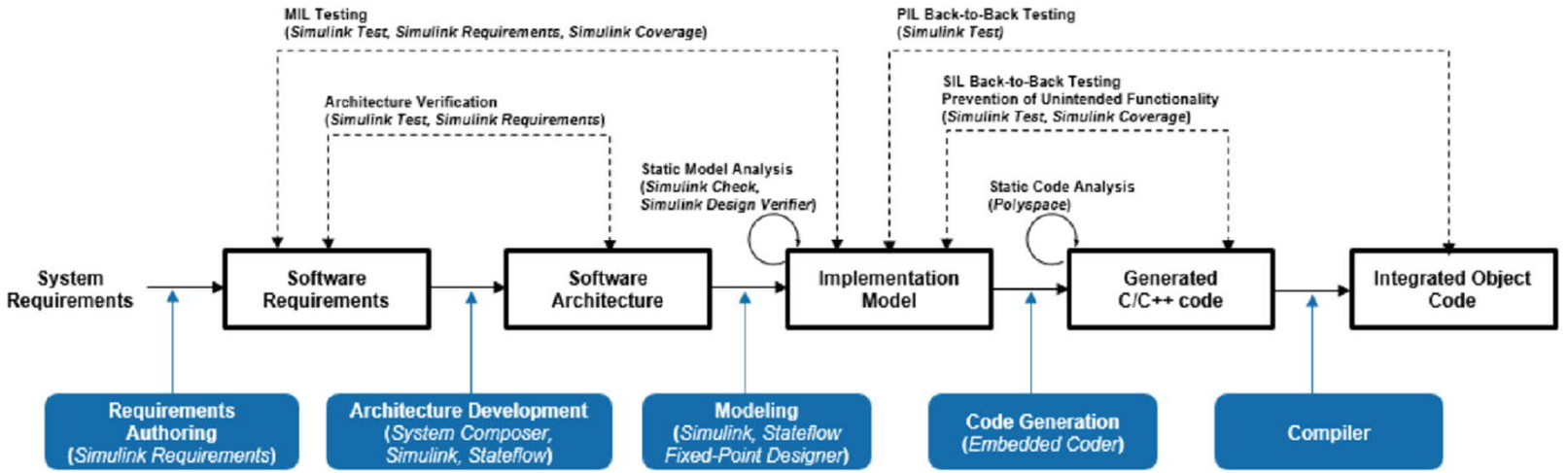
Source | EN ISO 13849-1 & ISO 12100:2010

Functional Safety

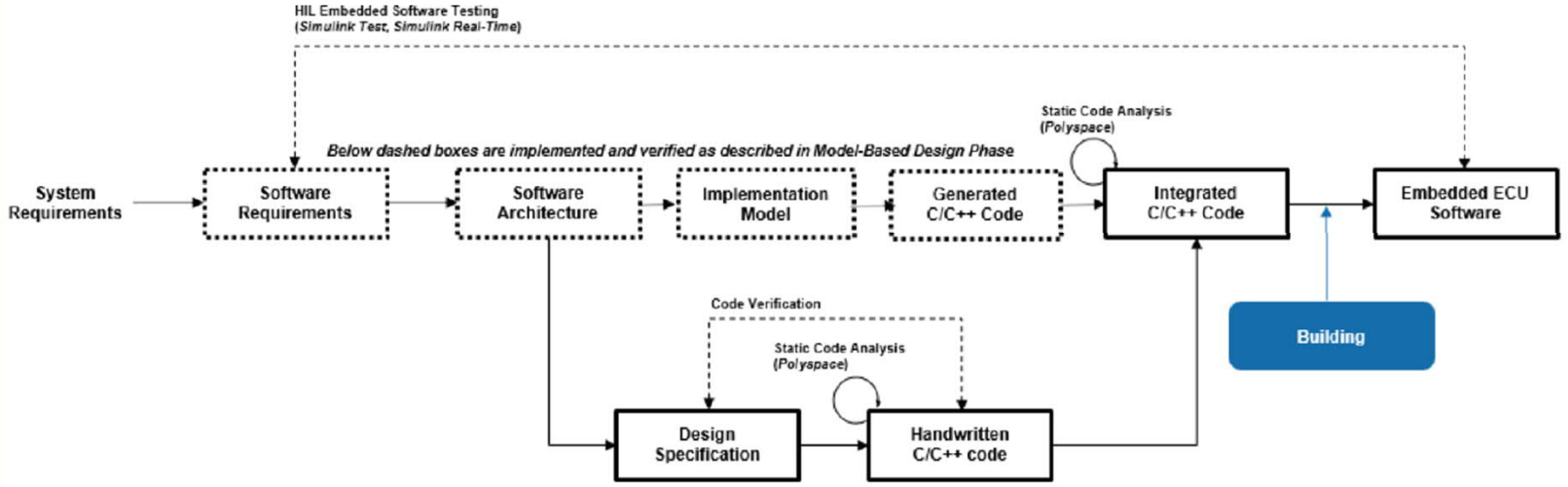
ISO 26262

- Aspects of electrical and/or electronic systems.
- Functional safety decomposition for systems, hardware, and software engineering

Phase 1: Model-Based Design



Phase 2: Embedded Software Testing

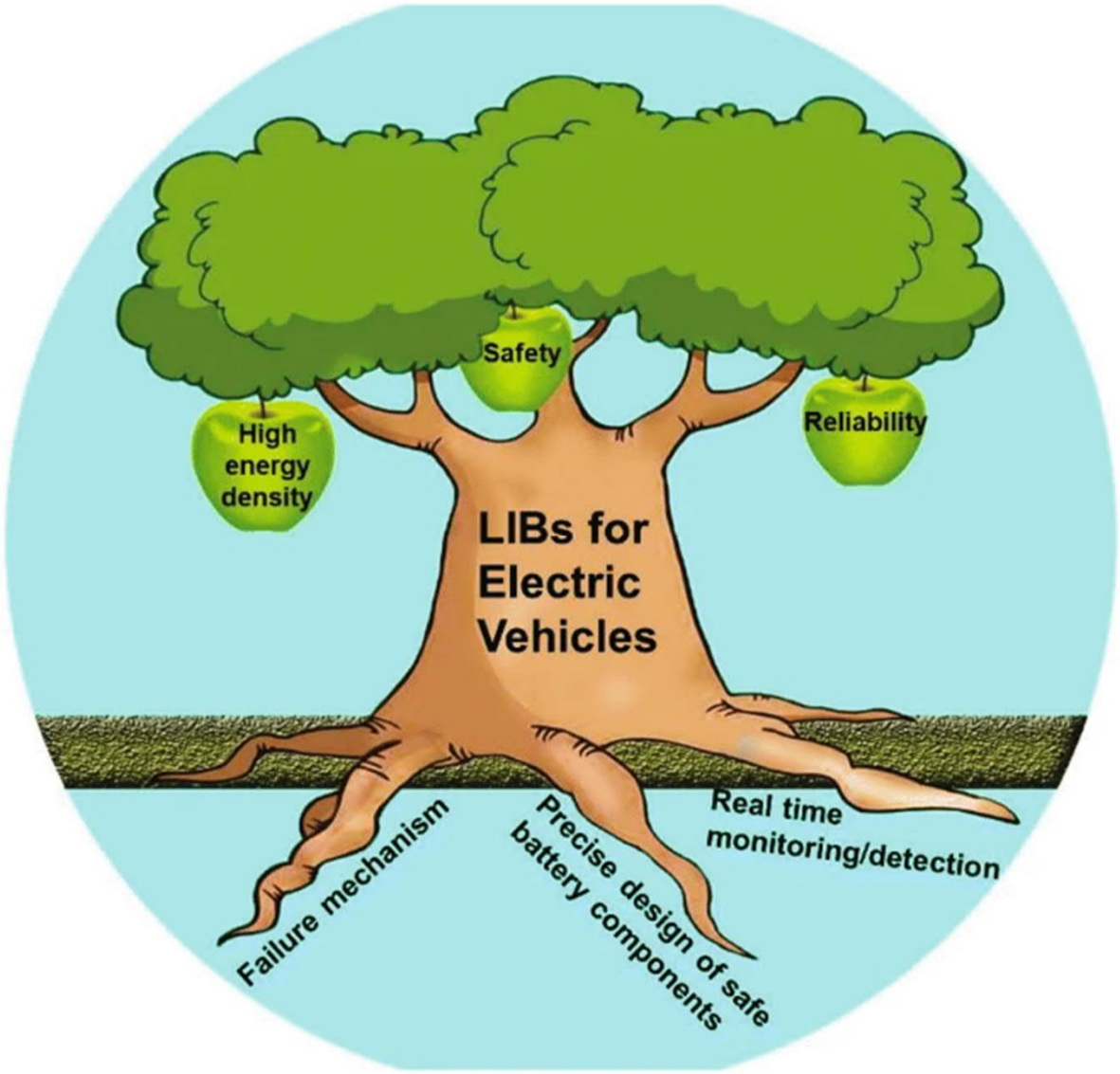


Source | Jason Moore and John Lee, Best Practices for Developing ISO 26262 Applications with Simulink; White Paper

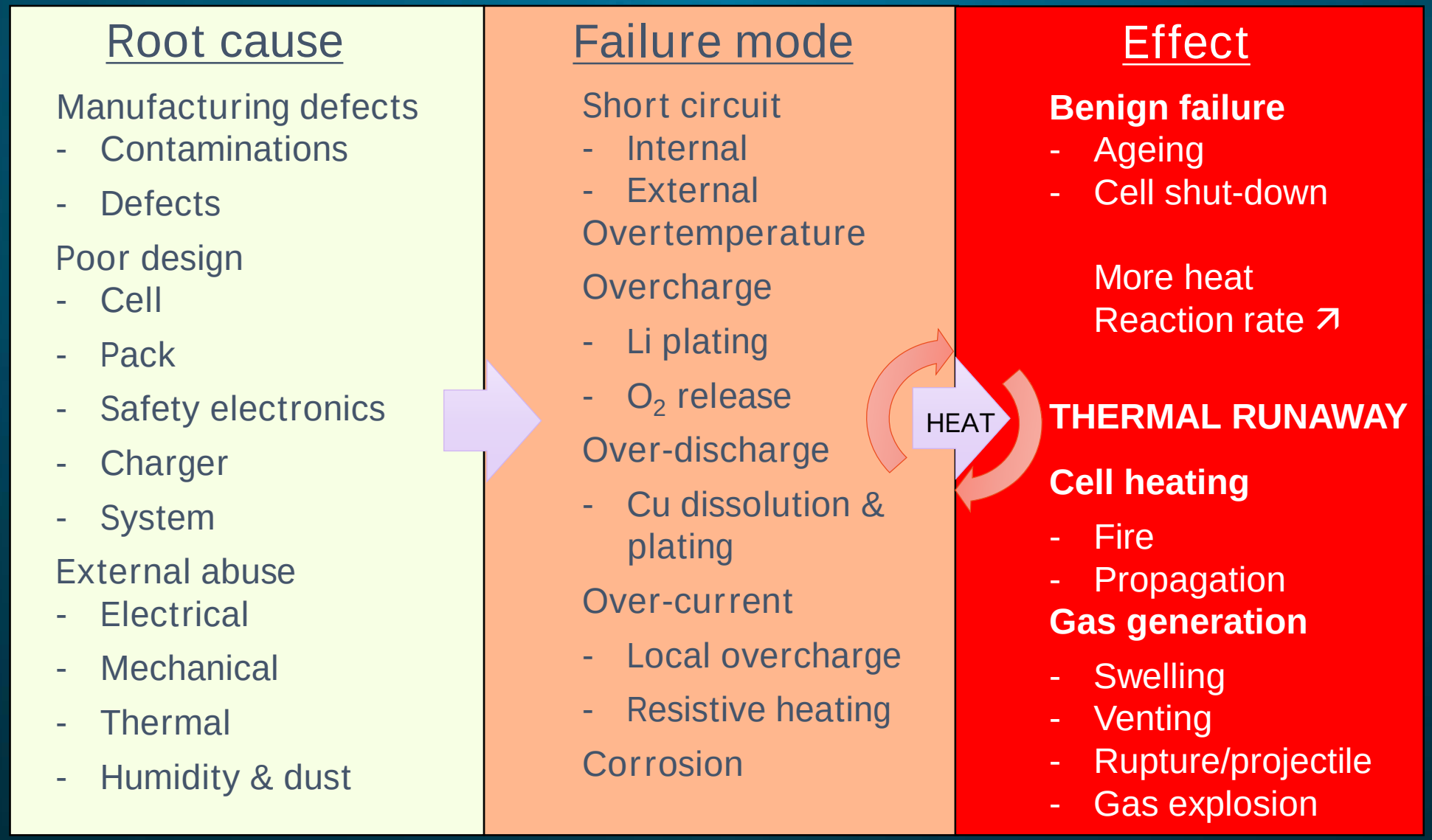
Risk Mitigation Strategies

Foster the Roots

Harvest the Fruits

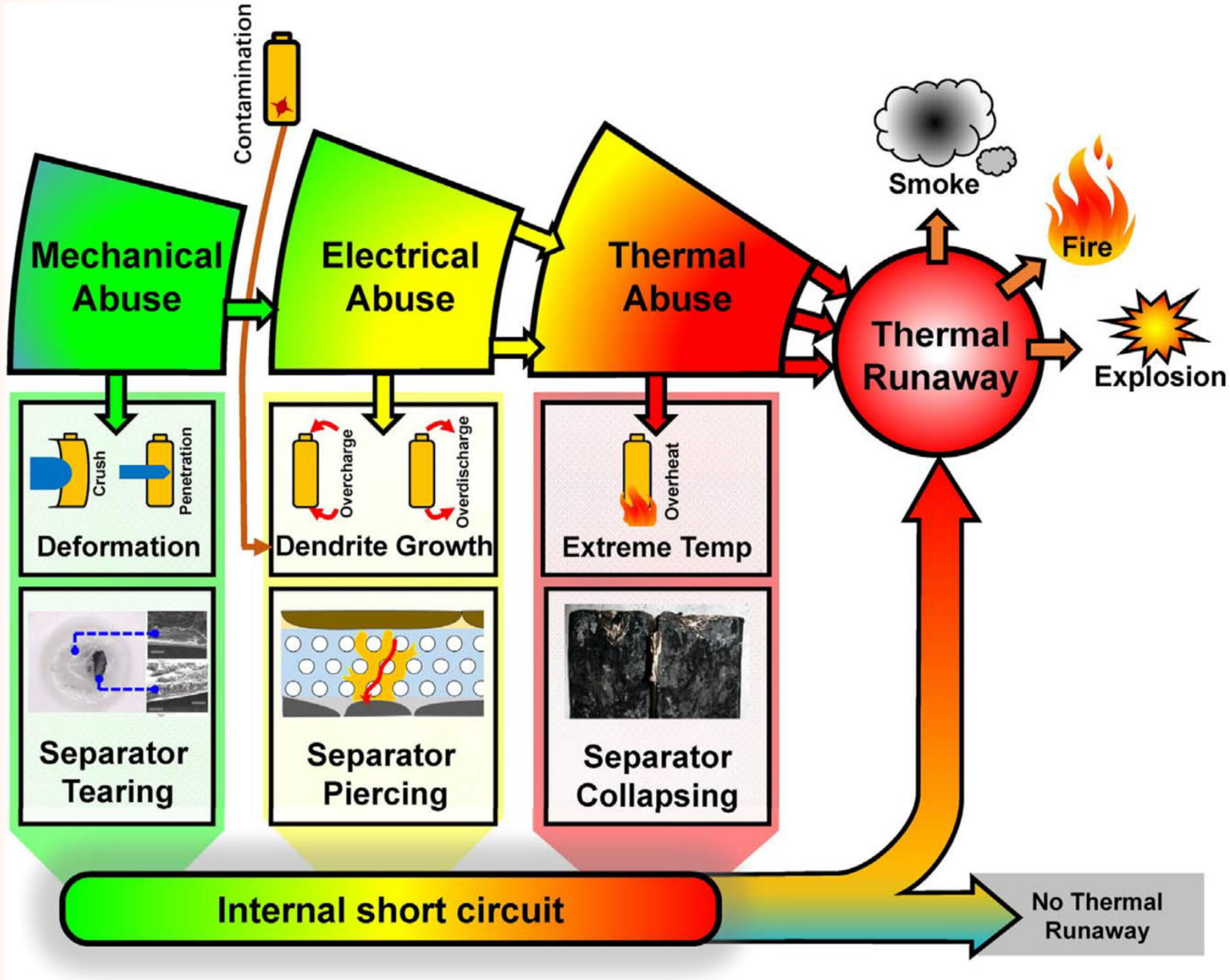


Sequence of events leading to battery failure



Thermal Runaway

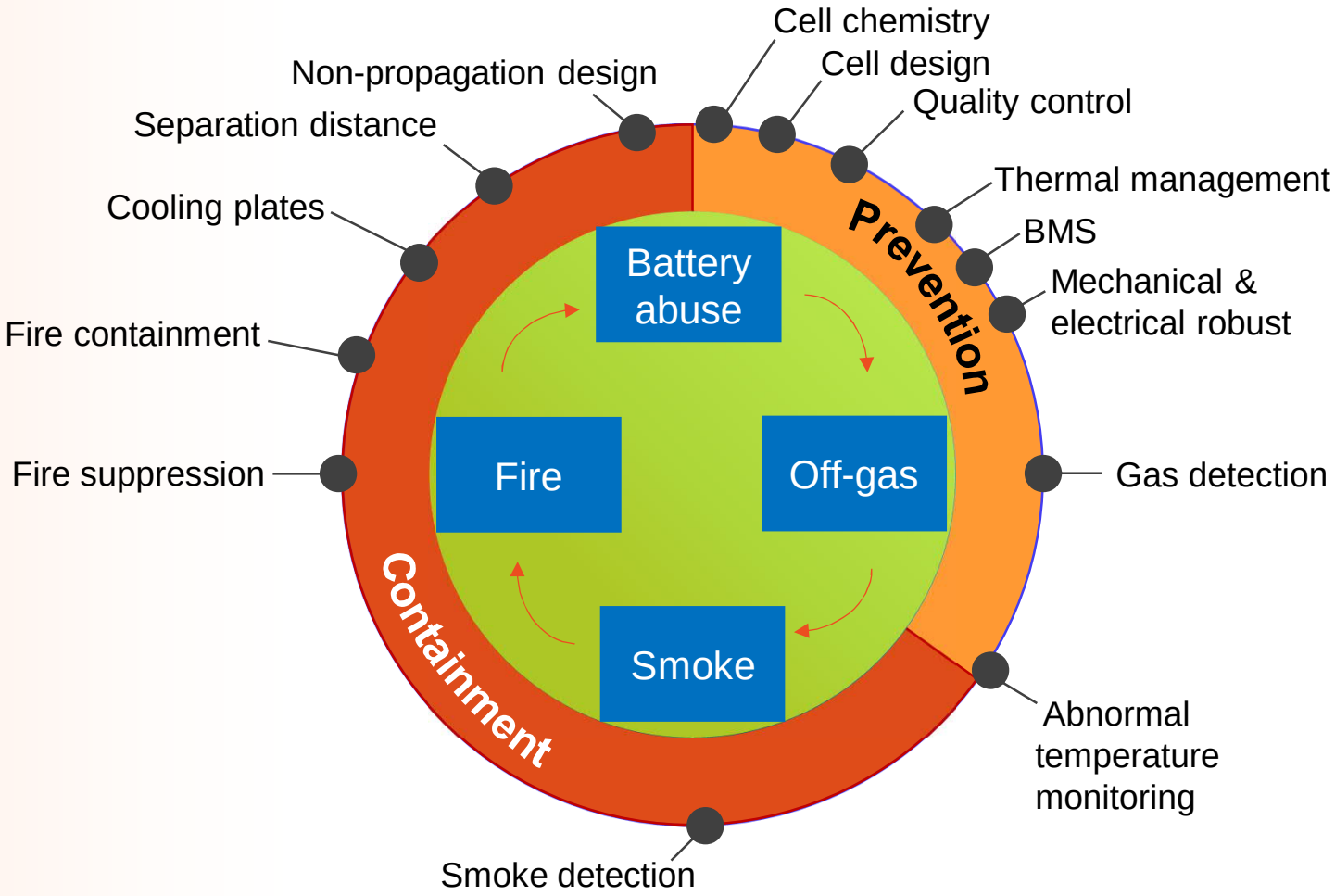
- Build-up of battery internal temperature
- Three Abuse Conditions



Internal short circuit: the most common feature of ThR (Feng et al. 2018)

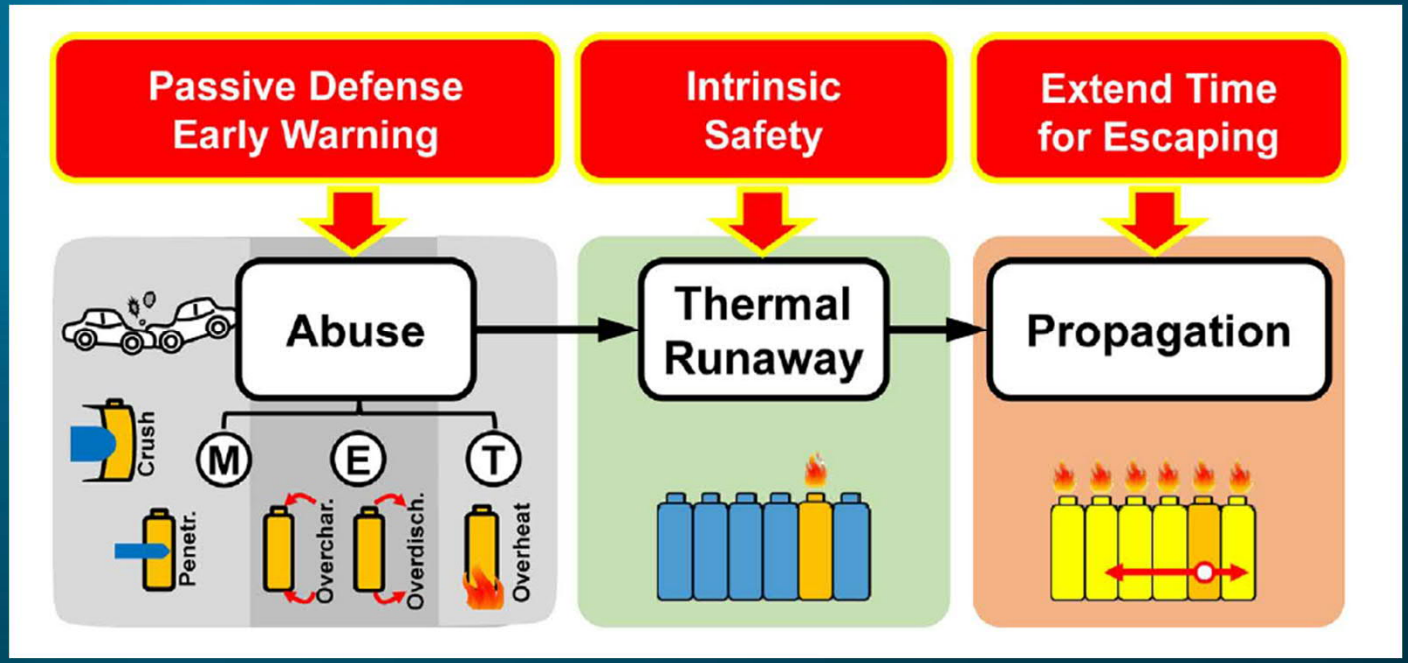
Design for Safety

- Mitigate failure consequences by design
- PREVENT
- CONTAIN



Key strategies for Li-ion batteries

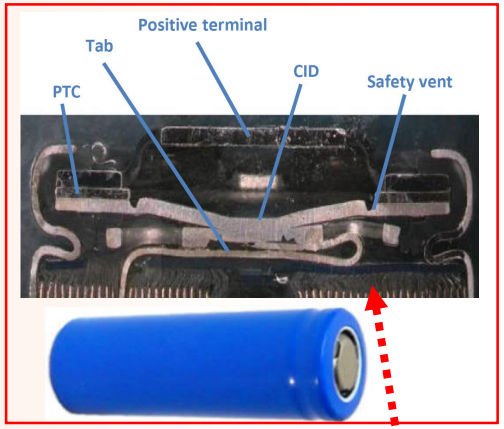
- Cell Design & Selection
- Mechanical Design
- Battery Management System (BMS)
  - *Monitoring & Control*
  - *Balancing*
- Environmental Consideration
  - *E.g. IP-class, insulation, corrosion*
- Thermal Management
  - *Active Cooling System*
  - *Thermal Insulation*
- Safety Features



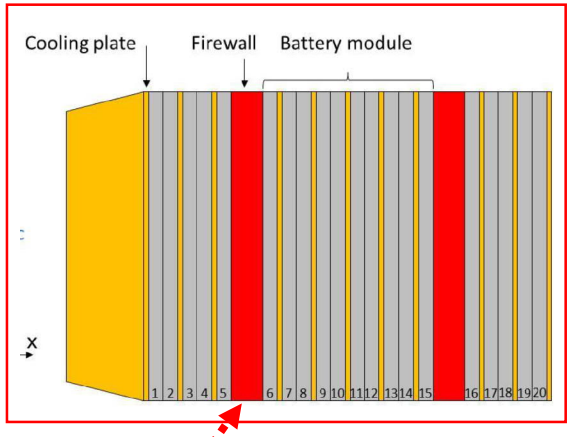
A three-level strategy of reducing hazard caused by thermal runaway (Feng et al. 2018)

Failure Propagation Mitigation

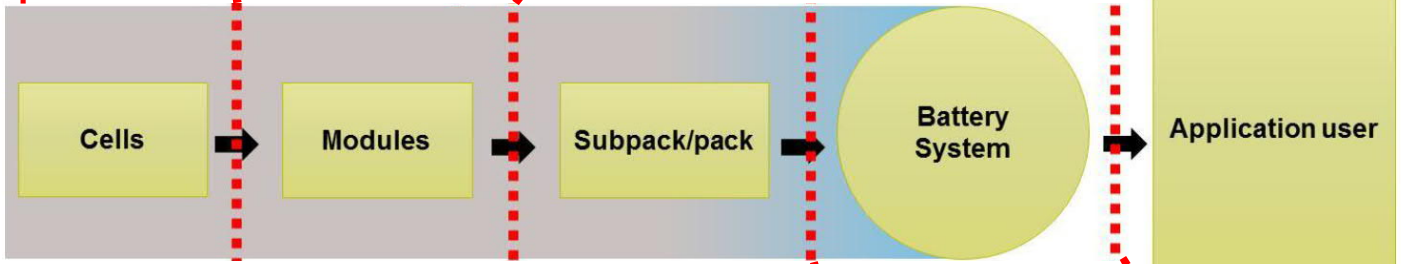
- Propagation (e.g. fire) can occur between many levels
- Important to stop the propagation or at least delay the propagation
- Multi-level failure mitigation strategies

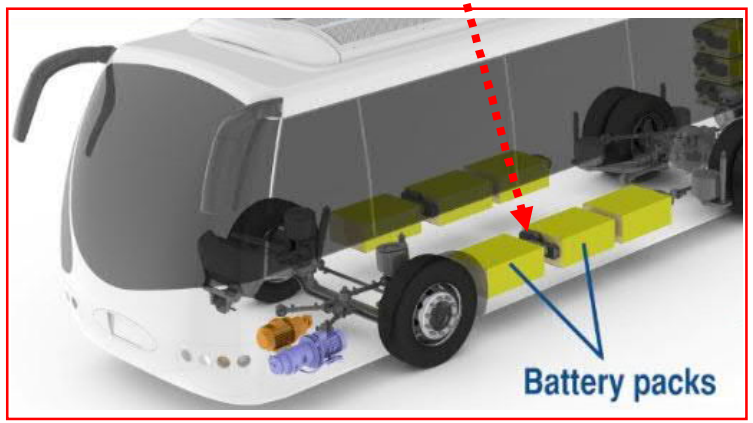


Cell-level safety components



Fire walls



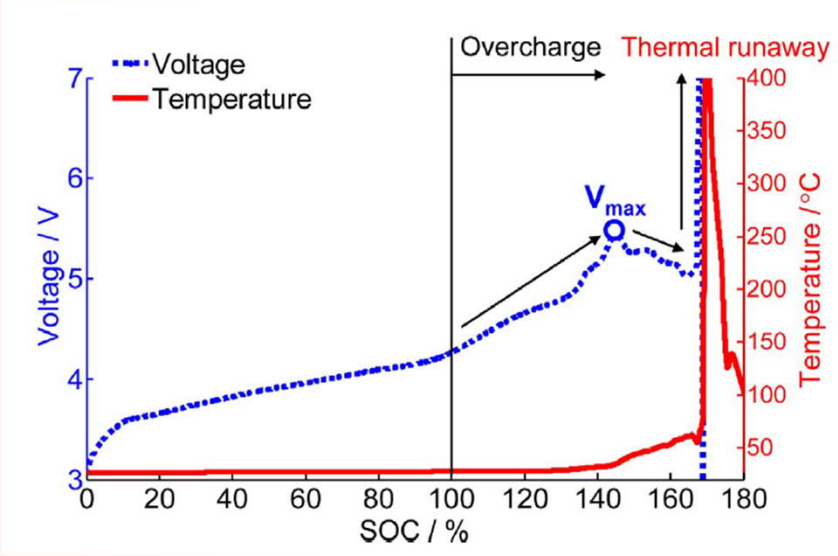


Spatial separation of (sub) packs

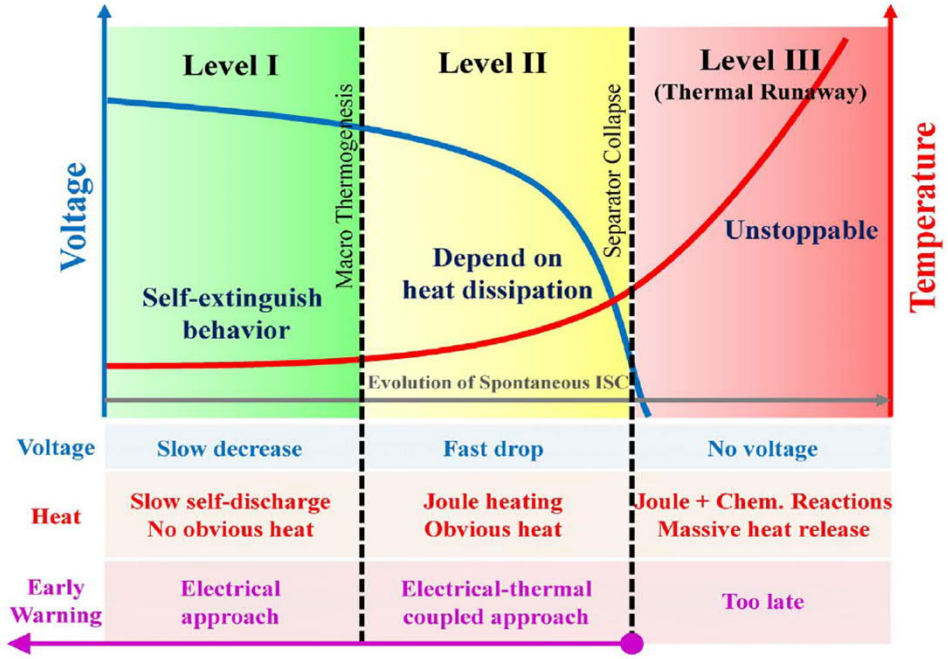
Gas filtration

Failure Propagation Mitigation

- Battery Management System (BMS)
  - Balancing
  - Monitoring & Control



The results of overcharge induced ThR for a commercial lithium-ion battery (Feng et al. 2018)

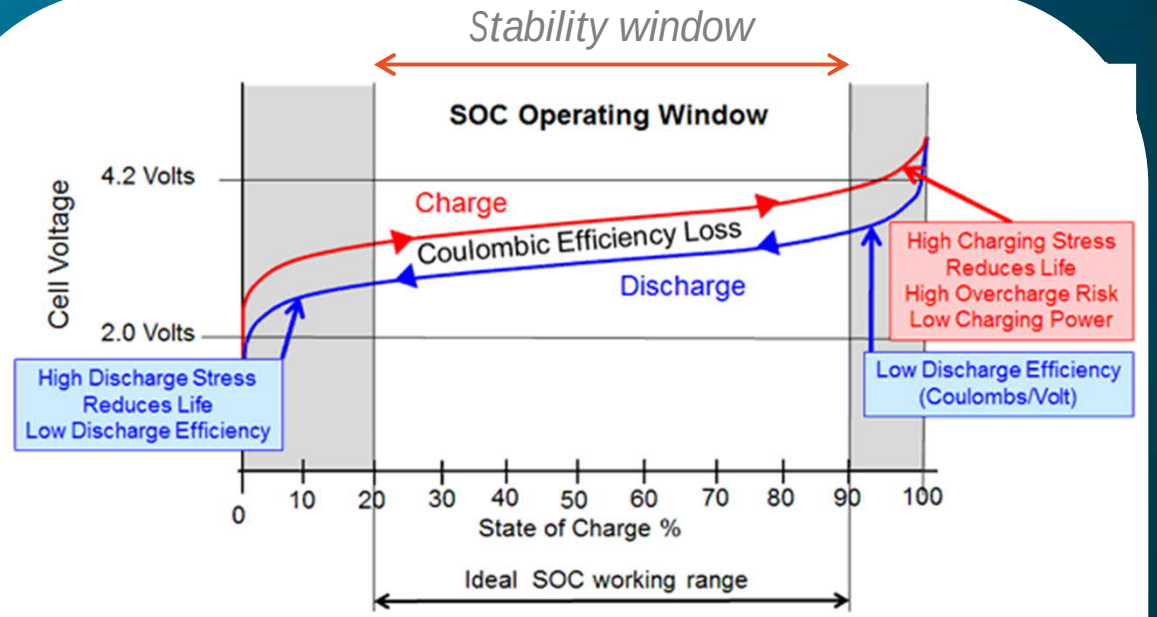


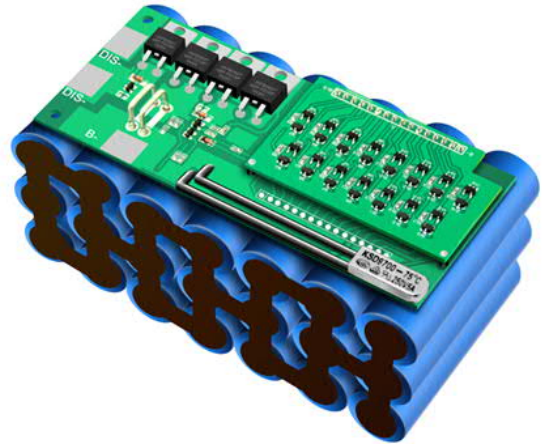
The three levels of internal short circuit (Feng et al. 2018)

Failure mode: Over-charge/discharge

Never use cells outside of specification!

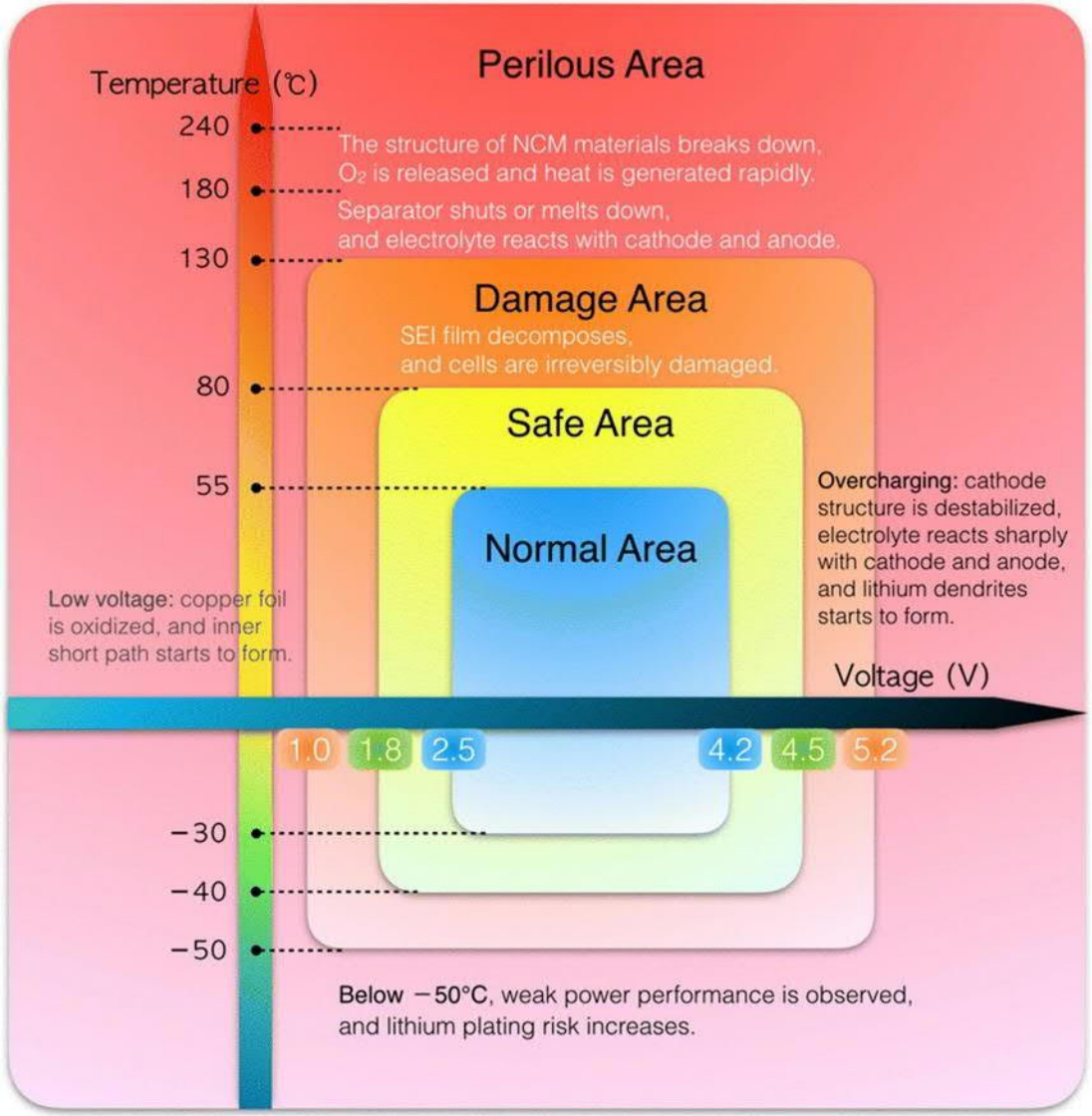
- Charging to voltages higher than the specified safe limit – e.g. >4.2 V per cell
- Discharging to voltages lower than the specified safe limit – e.g. <3.0 V per cell





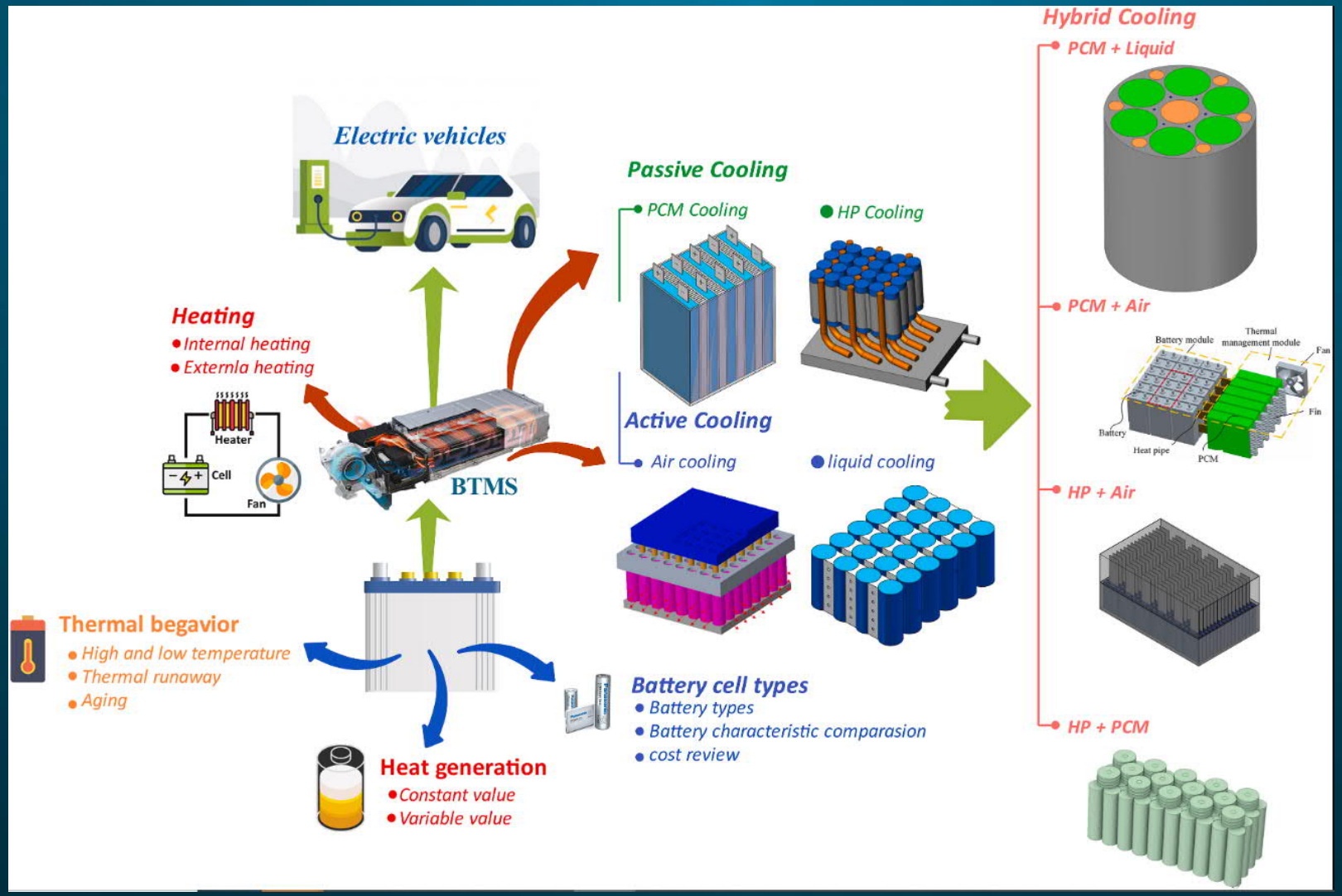
Failure Propagation Mitigation

- Thermal Management
  - Active Cooling System
  - Thermal Insulation



Operating voltage and temperature are two factors that impact Li safety. This example is for NCM cells. (Dung et al. 2020)

Failure mode: Overheating Control



Summary & Conclusion

- Safety Systems Overview
  - Battery Management Systems (BMS): Monitors and controls temperature, charge, and discharge rates.
  - Thermal Management: Uses cooling mechanisms to maintain safe operating temperatures.
  - Fault Detection: Identifies and mitigates potential issues before they escalate.
- Non-Negotiable Safety
  - Human Safety & Device Integrity
  - Regulatory Compliance

Conclusion

Compromising on safety for the sake of cost or development speed is not an option.

Prioritizing robust safety systems in Li-ion battery design is essential for protecting users, devices, and the company's reputation.

Questions?

For the better

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